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# Sustainability components affecting decisions for green building projects

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**Abstract**

Construction process is the broad mechanism for the realization of human settlements and the creation of infrastructure that supports development. This includes the extraction and beneficiation of raw materials, the manufacturing of construction materials and components, the construction project cycle from feasibility to deconstruction, and the management and operation of the built environment In Greece, the complex problems shared by cities are evidence of the impacts of urban sprawl. This research aims to investigate the sustainability components affecting decisions for green building projects. The research method is based on a questionnaire survey of thirty two participants who asked to assess nine sustainability components namely: Life cycle assessment, energy efficiency and renewable energy, water efficiency, environmentally preferable building materials and specifications, waste reduction, toxics reduction, indoor air quality, smart growth and sustainable development and environmentally innovative projects, which affect the decisions for green building projects. The respondent results indicate how participants prioritized the sustainability components ensuring a better quality of life inside buildings based on the principals of "green" buildings economy. Energy efficiency and renewable energy is considered of high priority followed by the reduction of toxic materials, indoor pollution and water saving.


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***Kewwords***: sustainability, green building projects, Life cycle assessment

## 1. Introduction

The Earth's ecosystems today are at a critical point. Human activities currently lead to irreversible losses of important ecosystem functions. Buildings and construction works have the largest single share in global resource use and pollution emission. In OECD countries the built environment is responsible for around 25-40% of total energy use, 30% of raw material use, 30-40% of global greenhouse gas emissions and


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for 30 to 40% of solid waste generation. In addition, in OECD countries, people spend almost 90% of their life inside buildings. In the United States, the annual cost of building-related sickness is estimated to be at 58 billion $. Consequently, healthy and comfortable indoor environments contribute significantly to human health and well-being and offer a large potential for reducing "external" costs to societies through lowering diseases (Chwieduk, 2002).

Construction process is the broad mechanism for the realization of human settlements and the creation of infrastructure that supports development. This includes the extraction and beneficiation of raw materials, the manufacturing of construction materials and components, the construction project cycle from feasibility to deconstruction, and the management and operation of the built environment (UNEP agenda 21, 1992).

Green construction refers to a structure and using process that is environmentally responsible and resource efficient throughout a building's life-cycle: from siting to design, construction, operation, maintenance, renovation, and demolition. Although new technologies are constantly being developed to complement current practices in creating sustainability structures, the common objective is that green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment.

US-EPA considers several projects types for sustainable construction. The projects must demonstrate at least a 20% savings in energy, an increase in water efficiency, or utilize green storm water practices that demonstrate new or innovative approaches to sustainable water management. This requires close cooperation of the design team, the architects, the engineers, and the client at all project stages. The Green Building practice expands and complements the classical building design concerns of economy, utility, durability, and comfort.

As far as the legislative framework is concerned the European Directive 2002/91/EC, includes the energy performance of buildings directive, which refers to the environmental information in energy certificates, particularly $CO_2$ emissions. Environmental performance is a major driving force for energy saving (climate change, exhaustion of resources, nuclear waste, toxicity aspects, etc.). Reducing environmental impact in the building sector requires appropriate evaluation methods (Jönsson, Å. 2000) allowing the following: i) Environmental performance levels to be integrated into programmers (clients' brief) by the authorities (e.g. requirements in municipal policy and building programs), ii) Advice to be provided to designers, architects and consultants, in order to reach such targets, iii) Guidance for efficient operation and management of buildings, so that actual performance corresponds to design performance, iv) Methods and tools to evaluate the most cost effective measures (actions) for energy savings and reduced environmental impact over the whole life cycle (Jönsson, Å. 2000).

In Greece, the complex problems shared by cities are evidence of the impacts of urban sprawl: increasing traffic congestion and commuting times, air pollution, inefficient energy consumption, loss of open space and habitat, non-optimal allocation of economic resources and the loss of a sense of community. These combined pressures, along with the challenges faced specifically by stakeholders of the built environment, have led to a growing awareness of the need for change. In response to these pressures the green projects are beginning to permeate the Greece construction industry as a possible strategy to meet the needs of clients and contractors while ensuring business success in an increasingly competitive and constrained operational environment (Vatalis et al., 2011).

Going towards green building projects in Greece a questionnaire survey was used in order to investigate the preferences of clients, brokers, contractors, engineers and construction companies concerning the real interest about the evolution of green building projects. Main purpose of this research is to estimate the overall level of interest for green building projects in Greece including how adoption varies by sustainable characteristics of the project, as well as the importance of weighted green components which affects the decision of participants in an environmental perspective.

## 2. Components of sustainable construction

Although new technologies are constantly being developed to complement current practices in creating more sustainable buildings, the common objective is that green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by the following goals of sustainable building : (a) Life cycle assessment (LCA), (b) Energy Efficiency and Renewable Energy, (c) Water Efficiency, d) Environmentally Preferable Building Materials and Specifications (e) Waste Reduction, (f)Toxics Reduction (g) Indoor Air Quality, (h) Smart Growth and Sustainable Development, (i) Environmentally Innovative materials and services (www.epa.gov).

### *2.1. Life Cycle Assessment, LCA*

Life cycle assessment (LCA) is a procedure (Figure 1) to assess environmental impacts associated with all the stages of a product's life from-cradle-to-grave (i.e., from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling). LCA can help avoid a narrow outlook on environmental concerns by: a) compiling an inventory of relevant energy and material inputs and environmental releases; b) Evaluating the potential impacts associated with identified inputs and releases; c) Interpreting the results to help make a more informed decision. LCA is a holistic procedure that requires the assessment of raw-material production, manufacture, distribution, use and disposal including all intervening transportation steps necessary or caused by the product's existence. The life cycle assessment process is defined under the ISO 14040/14044.

Especially in the buildings there is an interaction between all the stages of a building's life: for example, if less is invested in the construction phase (e.g. using poor insulation), the investment needed for use and maintenance will increase. So the question is: is it better to invest in construction rather than in use and maintenance? (Bribian et al., 2009).

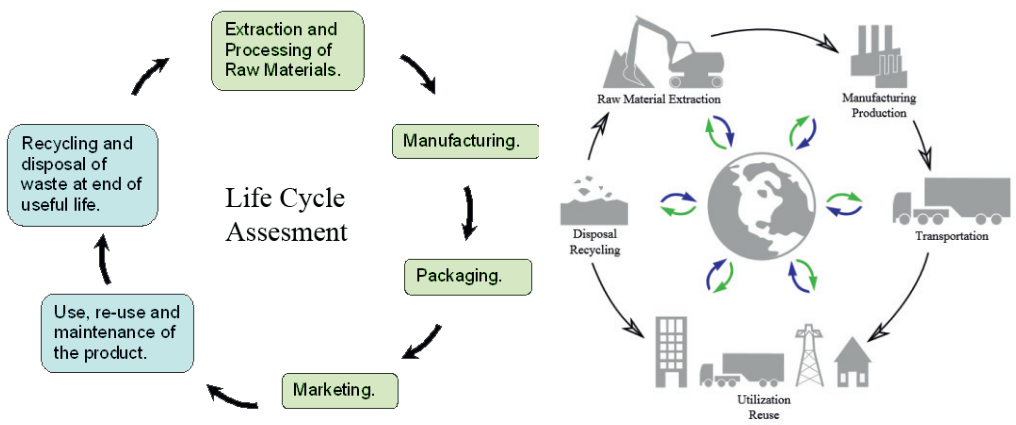



Fig. 1. *Scheme of LCA by a) Tececo and b)Westwind hardwood inc. 2012*

### *2.2. Energy efficiency and renewable energy in buildings*

Buildings have a significant impact on energy use and the environment. Commercial and residential buildings use almost 40% of the primary energy and approximately 70% of the electricity in the United States (EIA, 2005). The energy used by the building sector continues to increase, primarily because new buildings are constructed faster than old ones are retired. Electricity consumption in the commercial building sector doubled between 1980 and 2000, and is expected to increase another 50% by 2025 (EIA, 2005).

Energy efficiency is simply the ratio of energy services out to energy input. It means getting the most out of every unit of energy you buy. It is mainly a technical (and historical) process caused by stock turnover where old equipment is replaced by newer more efficient ones. It is generally a by-product of other social goals: productivity, comfort, monetary savings, or fuel competition. Measuring energy efficiency, particularly on a macro scale, is fraught with methodological problems and is very hard to measure over time, and between countries or sectors (Schipper and Haas, 1997). As pointed out by Hartley (1990), renewable energy technologies produce marketable energy by converting natural phenomena into useful energy forms. These technologies use the energy inherent in sunlight and its direct and indirect impacts on the Earth (photons, wind, falling water, heating effects, and plant growth), gravitational forces (the tides), and the heat of the Earth's core (geothermal) as the resources from which they produce energy. Energy-efficient buildings use less energy, cost less to operate, and improve comfort, saving money for homeowners and businesses.

### *2.3. Water efficiency*

During the next years, water efficiency and conservation will become critical element in green construction. Buildings consume 20% of the world's available water and water resources become scarcer each year, according to the United Nations Environmental Program. Water efficiency means using improved technologies and practices that deliver equal or better service with less water. Drinking water systems can implement water efficiency measures and still deliver an unchanged or improved level of service to consumers while reducing overhead costs. Improving water efficiency reduces operating costs (e.g., pumping and treatment) and reduces the need to develop new supplies and expand our water infrastructure. It also reduces withdrawals from limited freshwater supplies, leaving more water for future use and improving the ambient water quality and aquatic habitat (www.epa.gov).

The first step for increasing water efficiency at home is to reduce the use of drinking water for non-consumption purposes. There are two ways to do this: collect rainwater and reuse indoor wash water. You can install cisterns above or below ground that will collect and store run-off from rooftops and other impervious surfaces; as well as from laundry machines, dishwashers, bathtubs and sinks (this is classified as grey water, meaning that it does not include human waste or sewage).

### *2.4. Environmentally preferable building materials and specifications*

During construction or demolition phase building materials and components are often discarded with construction debris accounting for 28% of landfill waste in USA. The assessment of environmentally preferable building materials begins with the establishing criteria for the evaluation of building materials. The material criteria may differ per project. Criteria depend on if the project is a new construction, a renovation or an existing building. According to Froeschle 1999 there are sixteen environmental material criteria listed in Table 1. These criteria can help create more sustainable buildings. Project Specifications can help in three directions a) in environmental procedures, b) in environmentally friendly building materials and c) in environmental applications.

### *2.5 Waste building reduction*

Construction and demolition waste management has become one of the major environmental problems in many countries. There are two main kinds of building construction waste i) structure waste and ii) finishing waste (Skoyles and Skoyles, 1987). Concrete fragment, reinforcement bars, abandoned timber plate and pieces are generated as structure waste during the construction phase. Finishing waste is generated during the finishing stage of a building. Broken raw materials like mosaic, tiles, ceramics, paints and plastering materials are wasted because of careless use. Bossink and Brouwers (1996) estimated from a study that about 1-10% by weight of the purchased construction materials leave the sites of residential projects as waste. Ehshassi (1996) found from a study of 86 housing projects in the Gaza strip that the materials loss resulting from direct and indirect wastes was about 3.6-11%, which was significantly higher than the values that were normally allowed (2 - 4.5%).

**Table 1.** *Environmental material criteria for green buildings (Froeschle, 1999)*

| | *Criteria/variables* | Description |
|---|---|---|
| 1 | low toxicity | materials with reduced toxicity or nontoxic concentrations |
| 2 | minimal emissions | products with low or no chemical emissions (VOCs, CFCs) |
| 3 | low VOCs concentration | reduce the amount of indoor air contaminants |
| 4 | recycled content | products with identifiable recycled content |
| 5 | resource efficient | products manufactured with reduced energy consumption wastes & GHGs |
| 6 | recyclable materials | materials recyclable at the end of their useful life |
| 7 | reusable components | building components that can be reused or salvaged |
| 8 | sustainable sources | renewable natural materials harvested from sustainable sources |
| 9 | durable materials | material comparable to conventional with long life expectancies |
| 10 | moisture resistant | products that resist to moisture or inhibit the growth of contaminants |
| 11 | energy efficient | materials that help reduce energy consumption in buildings |
| 12 | water conserving | products and systems that help reduce water consumption |
| 13 | improved IAQ | systems or equipment that promote healthy IAQ |
| 14 | healthful maintenance | material that require simple and nontoxic cleaning |
| 15 | local product | regional materials saving energy and transportation to the project site |
| 16 | affordable material | building cost comparable to conventional material |

### *2.6 Toxics building reduction*

Many building materials emit air pollutants. Taking into consideration the reduction of toxic emissions from building materials, the effort is focused on three groups of indoor air pollutants: i)carcinogens, ii) irritants, and iii) odors. Human carcinogens, are few in number and cause severe diseases, for which reason their use should be avoided to the greatest practicable extent. The eye and airway irritants, are numerous and represent so many groups of chemical substances that great prospects for substitution exist. The odors should in general be avoided. These materials are used today as sealants, glues and adhesives paints, lacquers and wall/floor coatings (Andersen et al., 1982).

### *2.7 Indoor air quality*, IAQ

Indoor air quality problems are not limited to homes. Many office buildings have significant air pollution sources. Some of these buildings may be inadequately ventilated. For example, mechanical ventilation systems may not be designed or operated to provide adequate amounts of outdoor air. Providing a good indoor air quality in buildings does not refer to green buildings. People generally have less control over the indoor environment in their offices than they do in their homes. As a result, there has been an increase in the incidence of reported health problems. Some typical problematic VOCs compounds released from building materials include formaldehyde, acetaldehyde, toluene, isocyanates, xylene, and benzene. VOCs are often emitted at high levels and reduced to lower levels over time. In terms of indoor quality we mean air quality in acceptable levels. The most important indoor air quality (IAQ) control measures include ventilation and climate control Ventilation is viewed by many researchers as an essential process for the IAQ control. The main ventilation considerations for the IAQ control according (Levin 1991) are: 1) Dilution by outdoor air ventilation, 2) air intake locations, 3) building exhaust locations, 4) air cleaning and filtration, 5) space air distribution, 6) heat recovery and 7) microbial control.

### *2.8 Smart growth and sustainable development*

Sustainable development has been defined in many ways, but the most frequently quoted definition is from Our Common Future, also known as the Brundtland Report (WCED 1987), as follows: Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within two key concepts: a)the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given and b) the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.

Within framework smart growth is an urban planning and transportation concept that concentrates growth in compact walkable urban centers to avoid sprawl. Communities are using creative strategies to develop, preserve natural lands and critical environmental areas, protect water and air quality, and reuse already developed land, in the resources conservation by reinvesting in existing infrastructure and reclaiming historic buildings. By designing neighborhoods that have shops, offices, schools, churches, parks, and other amenities near homes, communities are giving their residents and visitors the option of walking, bicycling, taking public transportation, or driving as they go about their business. A range of different types of homes makes it possible for senior citizens to stay in their homes as they age, young people to afford their first home, and families at all stages in between to find a safe, attractive home they can afford. Through smart growth approaches that enhance neighborhoods and involve local residents in development decisions, these communities are creating vibrant places to live, work, and play. The high quality of life in these communities makes them economically competitive, creates business opportunities, and improves the local tax base (EPA, 2010).

### *2.9 Environmentally innovative projects and services*

Environmental innovation in construction is the development of projects that contribute to sustainable development. This includes a range of ideas, from environmentally friendly technological advances to socially acceptable innovative paths towards sustainability. Rapid changes in the economy and society create demands for new constructions of the built environment. Building innovations can provide the critical component of a competitive strategy in the construction sector. Investments in projects and in construction innovations and services are essential, but the initial high costs may make it difficult. A way to measure the annual innovative variation in construction sector is a composite indicator that ranks countries/economies/projects in terms of their environment to innovation and their innovation outputs. This indicator is called global innovation index.

## 3. Materials and methods

The research method is based on a questionnaire survey of 32 participants who were asked to assess nine sustainability components which affect the decisions for green building projects (Table 2). These were: 1) Life cycle assessment, 2) Energy efficiency and renewable energy of the buildings, 3) water efficiency, 4) environmentally preferable building materials and specifications, 5) waste reduction, 6) toxics reduction, 7) indoor air quality, 8) smart growth and sustainable development and 9) Environmentally innovative projects. The criteria for the selection of participants were: a) practitioners should have extensive working experience in the green construction sector; b) clients should be interested to acquire a space in a green construction project, c) Group or banking investors are willing to promote green building projects in Greece.

Table 2. Rating criteria of sustainability components

| | Components | rating criteria | | | | | | | | | | Consideration weight | Net score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | |
| $X_1$ | Life Cycle Assessment | | | | | | | | | | | 0.1 | 0.580 |
| $X_2$ | Energy Efficiency & Renewable Energy | | | | | | | | | | | 0.15 | 1.159 |
| $X_3$ | Water Efficiency | | | | | | | | | | | 0.1 | 0.727 |
| $X_4$ | Environmentally Preferable Building Materials & Specifications | | | | | | | | | | | 0.1 | 0.597 |
| $X_5$ | Waste Reduction | | | | | | | | | | | 0.1 | 0.627 |
| $X_6$ | Toxics Reduction | | | | | | | | | | | 0.15 | 1.155 |
| $X_7$ | Indoor Air Quality | | | | | | | | | | | 0.1 | 0.747 |
| $X_8$ | Smart Growth & Sustainable Development | | | | | | | | | | | 0.1 | 0.503 |
| $X_9$ | Environmentally Innovative Projects | | | | | | | | | | | 0.1 | 0.717 |
| | Totals | | | | | | | | | | | 1.0 | |

A total of 32 participants were asked to fill the above questionnaire according to the intensity of the rating criteria with a range from 1 to 10 as described in Table 3. The weights of components (Table 2) have been defined according the international literature (Vatalis and Kaliambakos 2006) and the resulting net score presents the value of rating x weight.

Table 3. Ranking importance of green components

| Rank | description of importance |
|---|---|
| 1 | indifferent |
| 2 | low importance |
| 3 | weak or slight importance |
| 4 | moderate importance |
| 5 | moderate plus |
| 6 | strong importance |
| 7 | strong plus |
| 8 | very strong or demonstrated importance |
| 9 | very-very strong |
| 10 | absolute importance |

Thirty two questionnaires were returned from the participants whose identity described as follows: a) clients with particular interest to live in green buildings, fifteen of them 15, b) brokers (seven) 7, c) Construction engineers - Managers (five) 5, d) Contactors - developers (three) 3 and e) funds (two) 2.

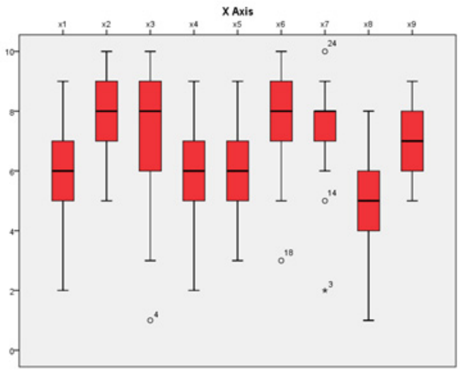
## 4. Results and discussion

The respondent results indicate how participants prioritized the sustainability components. Energy efficiency and renewable energy ($X_2$) followed by toxics reduction in the buildings ($X_6$) were the most important component of the respondents. From the statistical analysis (Table 4 and Figure 2) of the answers result that, the variables $X_2$ (energy efficiency) and $X_3$ (water efficiency) are linear correlated, with Pearson correlation 0.387 and sig. 0.035. The $X_8$ component (Smart growth and sustainable development) is linear correlated with the $X_3$ (Water efficiency) and $X_8$ (Smart growth) components. The Pearson correlation for $X_8$ (Smart growth) in relation with $X_3$ (water efficiency) are -0.410 and sig. 0.024 while for $X_8$ (Smart growth) in relation $X_6$ (toxic reduction) Pearson correlation is 0.481 and sig. 0.007.

Table 4. Descriptive statistics and assessment of variables

| X | Mean | SD | 95% confidence lower - upper | rank |
|---|---|---|---|---|
| $X_1$ | 5.8 | 1.71 | 5.16 - 6.43 | 8 |
| $X_2$ | 7.7 | 1.31 | 7.24 - 8.22 | 1 |
| $X_3$ | 7.2 | 2.04 | 6.50 - 8.03 | 4 |
| $X_4$ | 5.9 | 1.79 | 5.29 - 6.63 | 7 |
| $X_5$ | 6.2 | 1.59 | 5.67 - 6.86 | 6 |
| $X_6$ | 7.7 | 8.00 | 7.18 - 8.21 | 2 |
| $X_7$ | 7.4 | 1.43 | 6.93 - 8.00 | 3 |
| $X_8$ | 5.0 | 1.69 | 4.40 - 5.66 | 9 |
| $X_9$ | 7.1 | 1.20 | 6.71 - 7.61 | 5 |

Figure 2. Mean values of components




The ranking sustainability components (Table 4) indicate that the $X_2$ component regarding the Energy efficiency and renewable energy of the buildings is the most important component of the sustainable construction. As second factor comes the $X_6$ toxics reduction in the buildings. Third component is the indoor air pollution ($X_7$) affects all the income levels. Water efficiency ($X_3$) remains the forth component in priority of importance. Pressures today caused by lack of safe drinking water under the stress from national economic sectors give us opportunities and provide incentives to initiate processes leading to improved water management of building projects. For example the recycled water can satisfy most water demands, as long as it is adequately treated to ensure water quality appropriate for large scale use. As a fifth component in order of importance comes the preference of respondents' to share Environmental innovative projects ($X_9$). Environmental innovation tries to respond in pollution abatement expenditures in building projects. Sixth priority is the waste reduction in buildings ($X_5$). The rapid urbanization of Greece in recent years and the irrational management of wastes are associated with environmental pressures, such as reduction of the quality of life and the well-being of the population, followed by the environmentally preferable building materials and specifications ($X_4$). It is known that the materials from which a building is constructed make a significant contribution to its overall impact on the environment. The conservation of material and improved techniques reduce the environmental impact of buildings and create more resource-efficient models of construction, renovation, operation and maintenance. Under these circumstances, Life cycle assessment ($X_1$) is assessed as the eighth most important variable in sustainable construction. Finally, the success of the principle of smart growth and sustainable development ($X_8$) was ranked as the least important factor in sustainable construction.

Sustainable building with its multiple benefits for enterprises and the stakeholders, cooperating organizations and consumers that have been pointed by the analysis, constitute a direct necessity this period of time in Greece (Papadopoulos et al., 2012).

## 5. Conclusions

Buildings from the sustainable point of view are considered during the life cycle assessment a key toward the improvement of environmental quality and energy conservation. The conclusions research are that people should live in an environment that is designed and operates incorporating a) energy efficiency and renewable energy, b) with reduction of toxic materials c) without indoor pollution, d) water saving, e) with trust in environmentally innovative projects f) in waste minimization and pollution prevention, g) reuse of friendly building materials in order to achieve sustainable development also ensuring a better quality of life inside buildings based on the principals of "green buildings economy. At the moment due to the deep economic crisis there is no strategy for green construction projects in Greece. It is to be hoped that the development of experience, knowledge of economic benefits and competence will encourage developers, occupiers and authorities to support an interactive strategy among the different actors involved in construction in the country.

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